Partial Discharge

PD

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The Partial Discharge (**PD**) considered as a **Disease** which affect on your equipments

((Gen. , Motor , Transformer , GIS ,Cables))

through the **insulation** causing early destruction of your equipments before it's expected age

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What Is Partial Discharge (PD) ?

Partial Discharges (PD) are ionizations or "sparks" occurring in voids or gaps within, or on the surface of, insulation, without any insulation **breakdown**.

Origin of the term by source of activity

INTERNAL = PD vs. EXTERNAL = Corona

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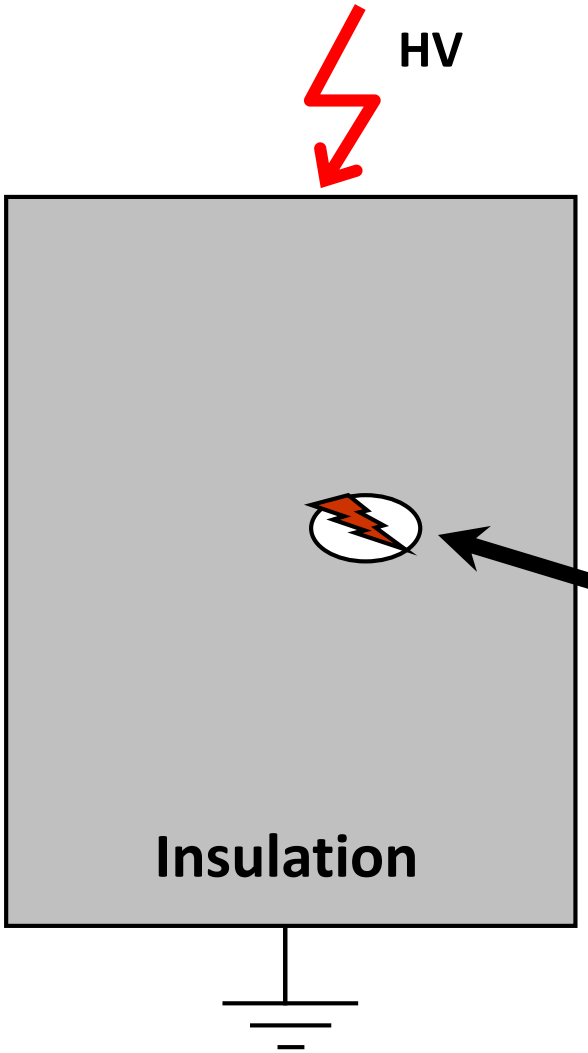


It's Occur Where :

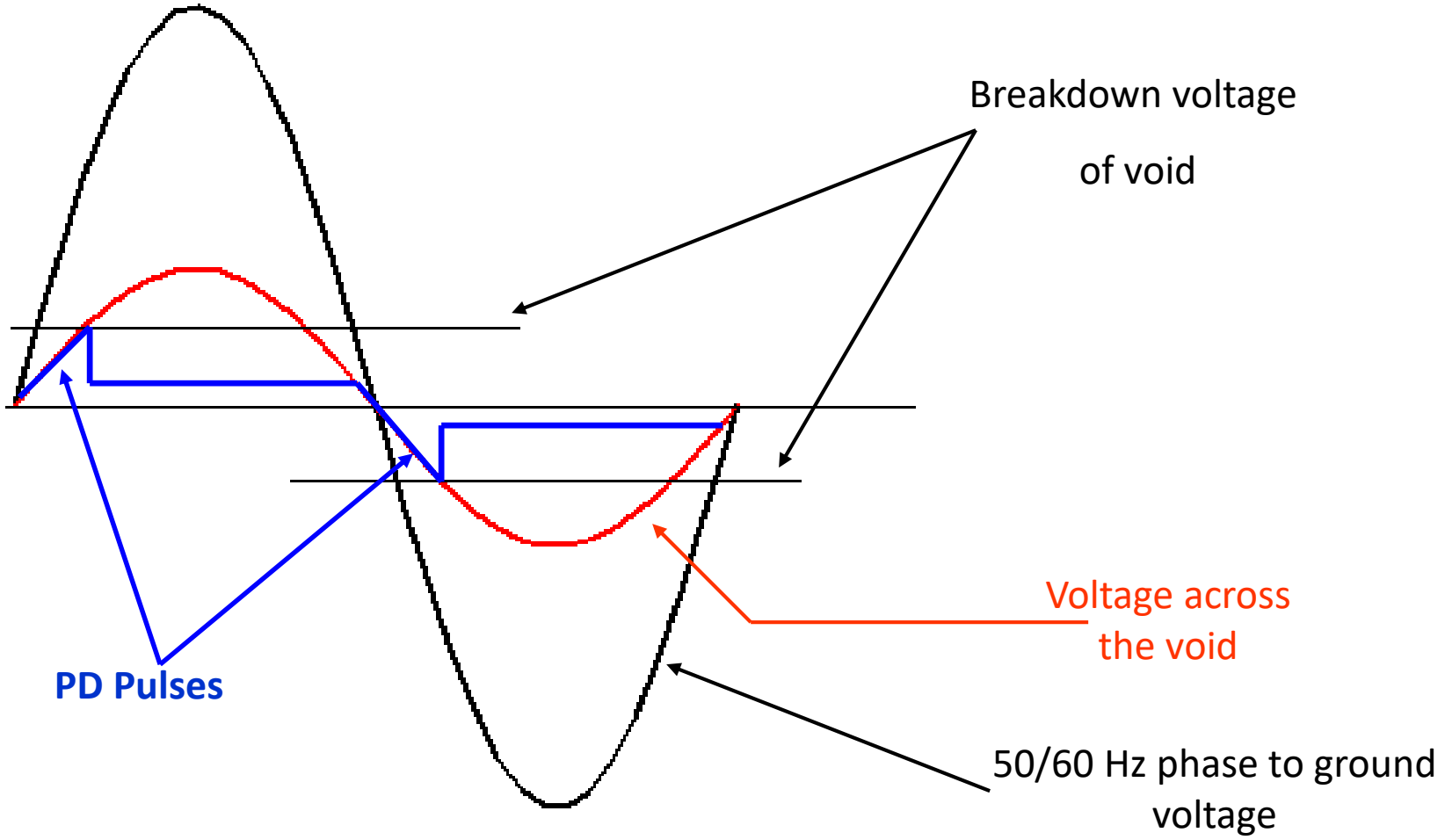
air (3 kV/mm) < solid insulation (~300 kV/mm)

The discharge occurs in the void itself ,

Not full breakdown

So PD creates small local ionises

What is Partial Discharge?



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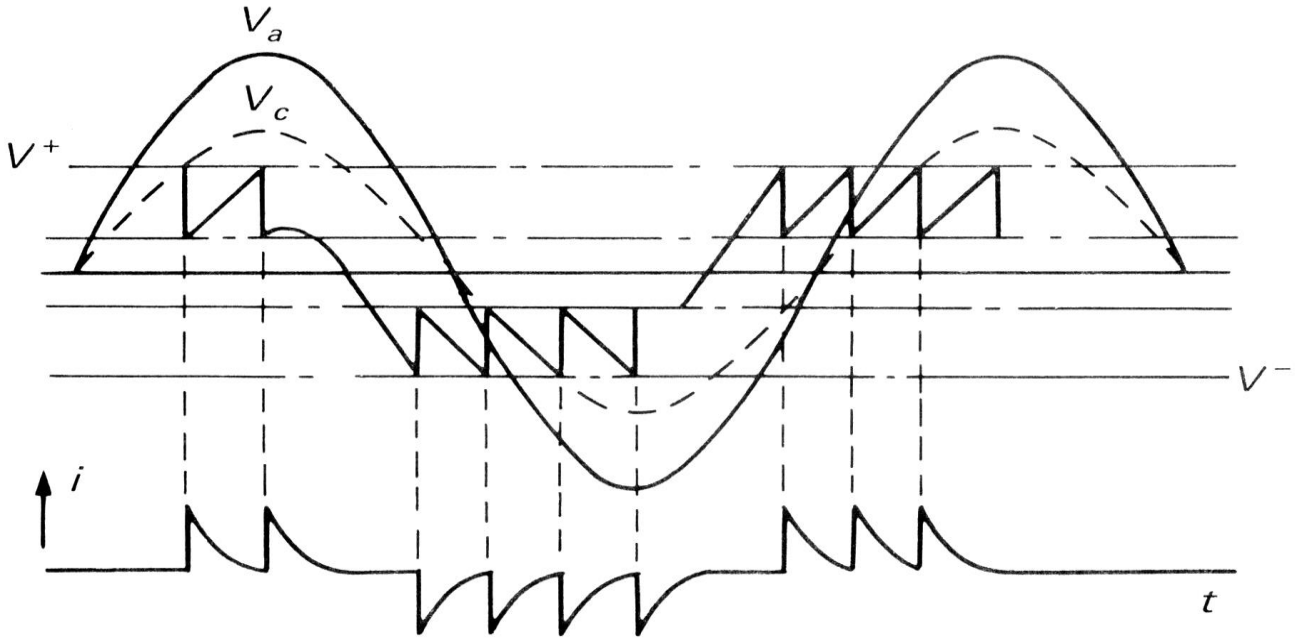
V_a
V_c
V^+
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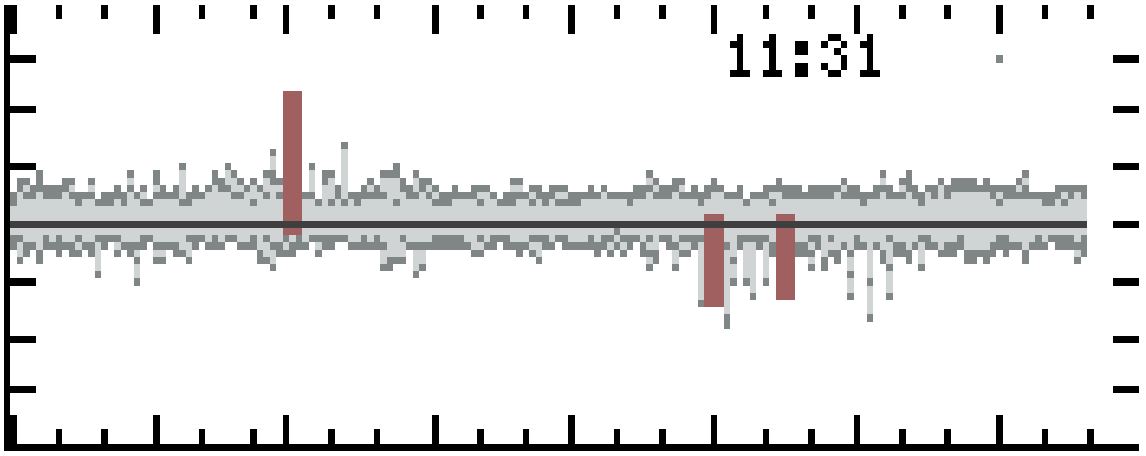
i
t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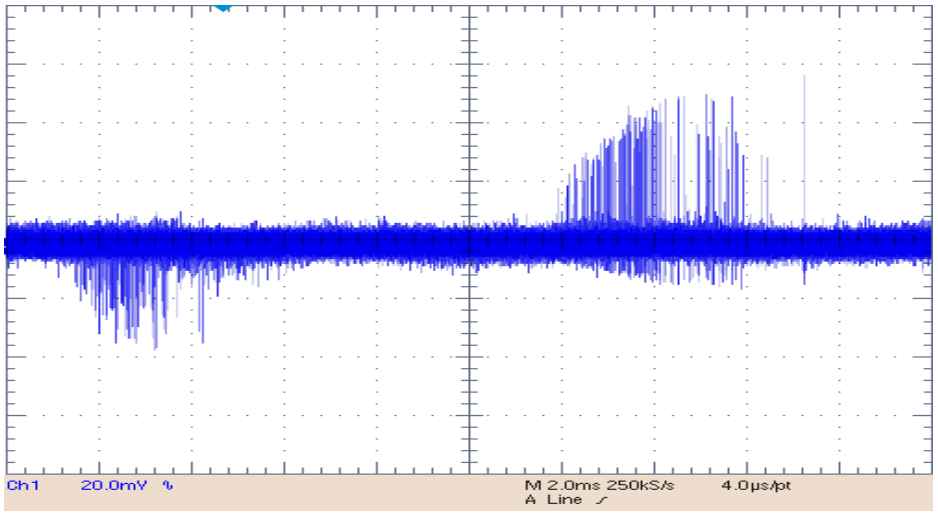
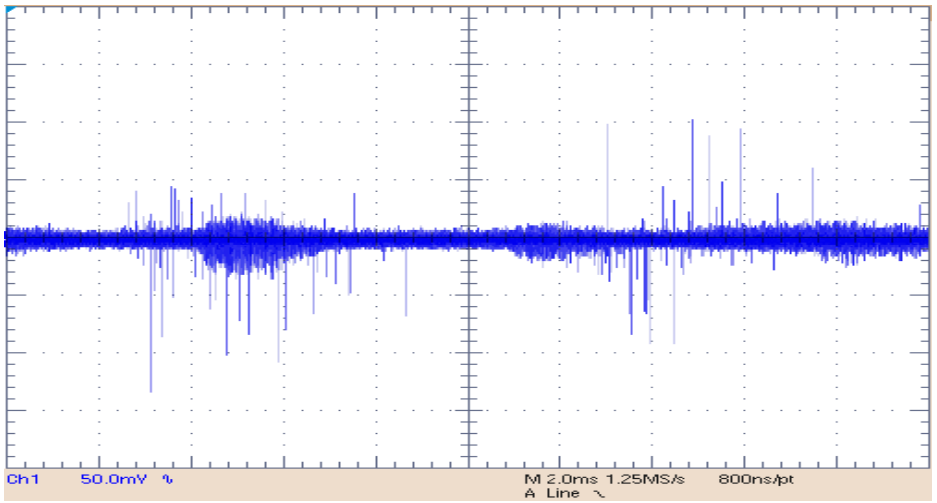
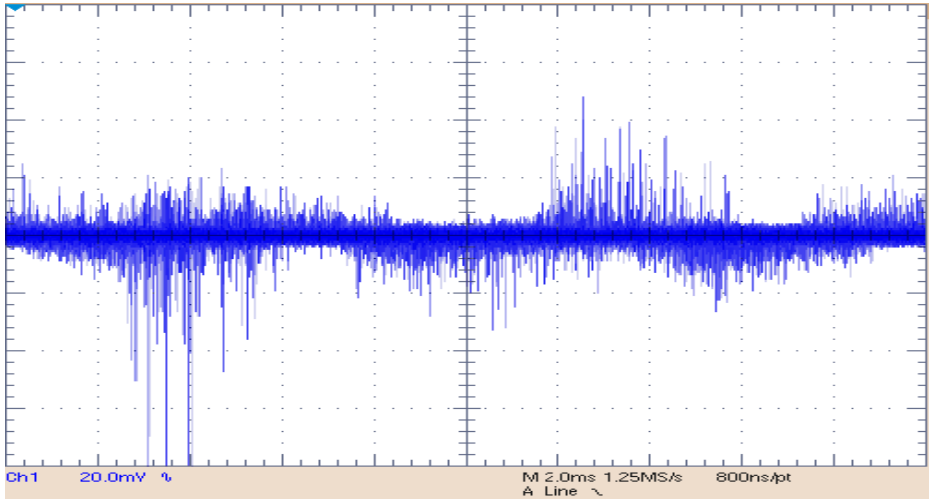
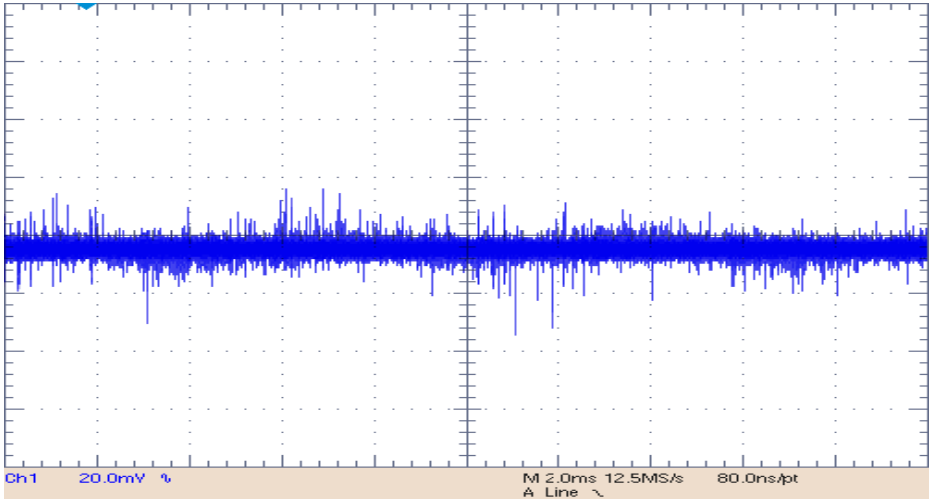

Ch1 20.0mV %
M 2.0ms 250kS/s 4.0µs/pt
A Line


Ch1 50.0mV %
M 2.0ms 1.25MS/s 800ns/pt
A Line


Ch1 20.0mV %
M 2.0ms 1.25MS/s 800ns/pt
A Line

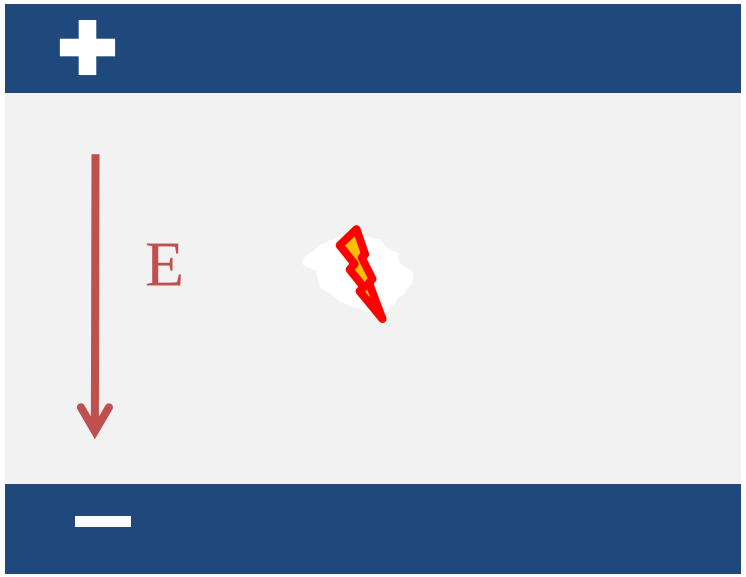

Ch1 20.0mV %
M 2.0ms 12.5MS/s 80.0ns/pt
A Line

Steps of PD Streamer Process

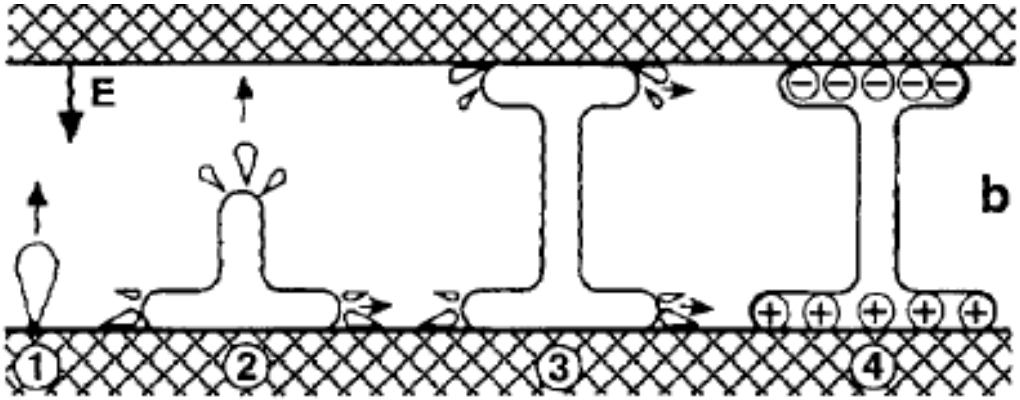
HV Conductor

Insulation

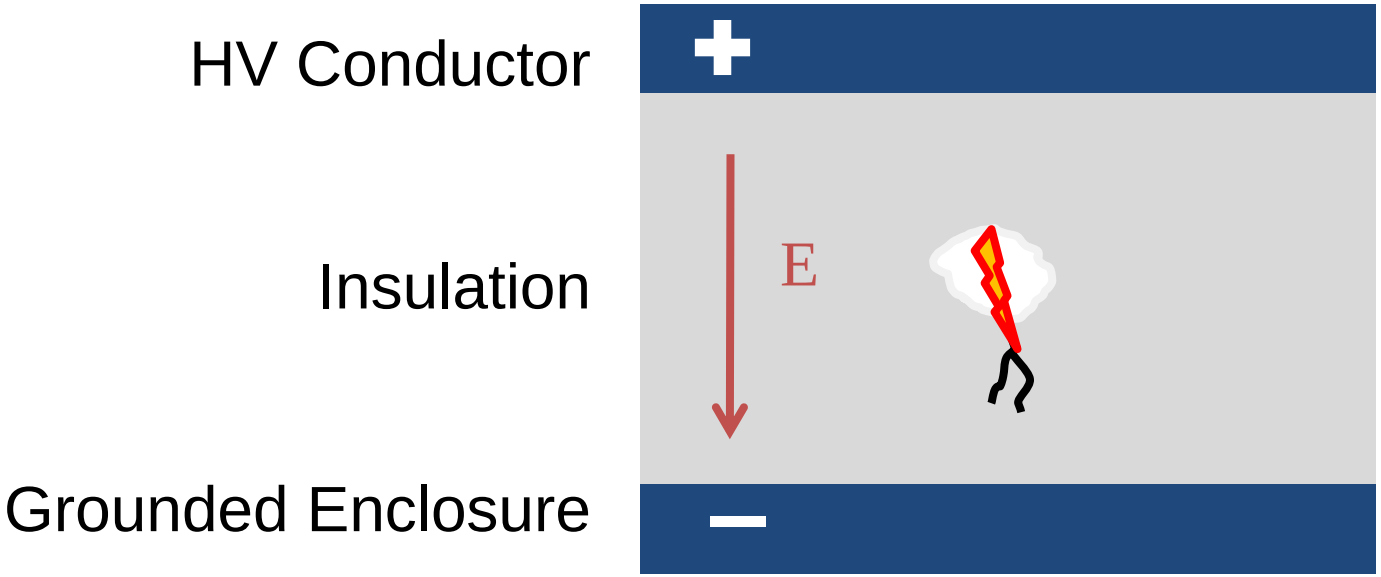
Grounded Enclosure



Streamer Discharge Process



Void Turning into Treeing



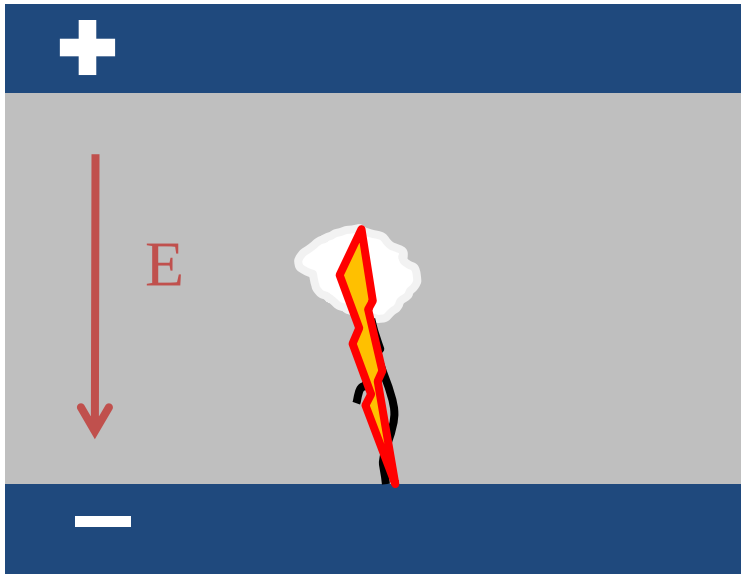
After a certain period depending on **material parameters** and discharge conditions cumulated PD energy cracks the surface of the void and initiates treeing PD.

PD Close to Breakdown

HV Conductor

Insulation

Grounded Enclosure



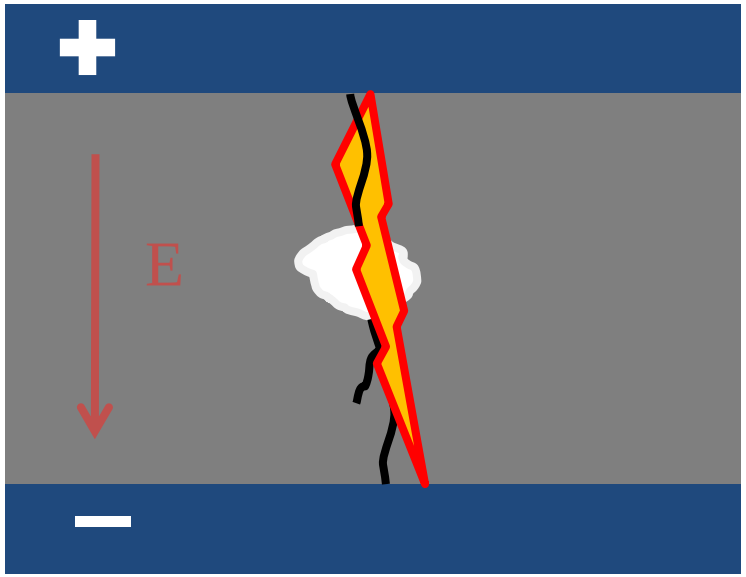
Treeing PD grows dynamically and reaches one of the electrodes.

Final Breakdown

HV Conductor

Insulation

Grounded Enclosure



Finally treeing PD **breaks up material** and short circuits the whole isolation distance, the final breakdown takes place.

Causes of partial discharge in Generators

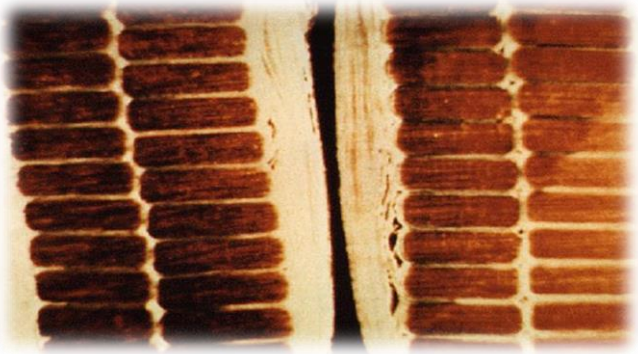
PD a Symptom or Cause of Many Failure Processes

Internal

- **Thermal Deterioration**

Such as: overloads, defective cooling, unbalanced phase voltage and poor design

- **Load cycling**
- **Inadequate bonding**

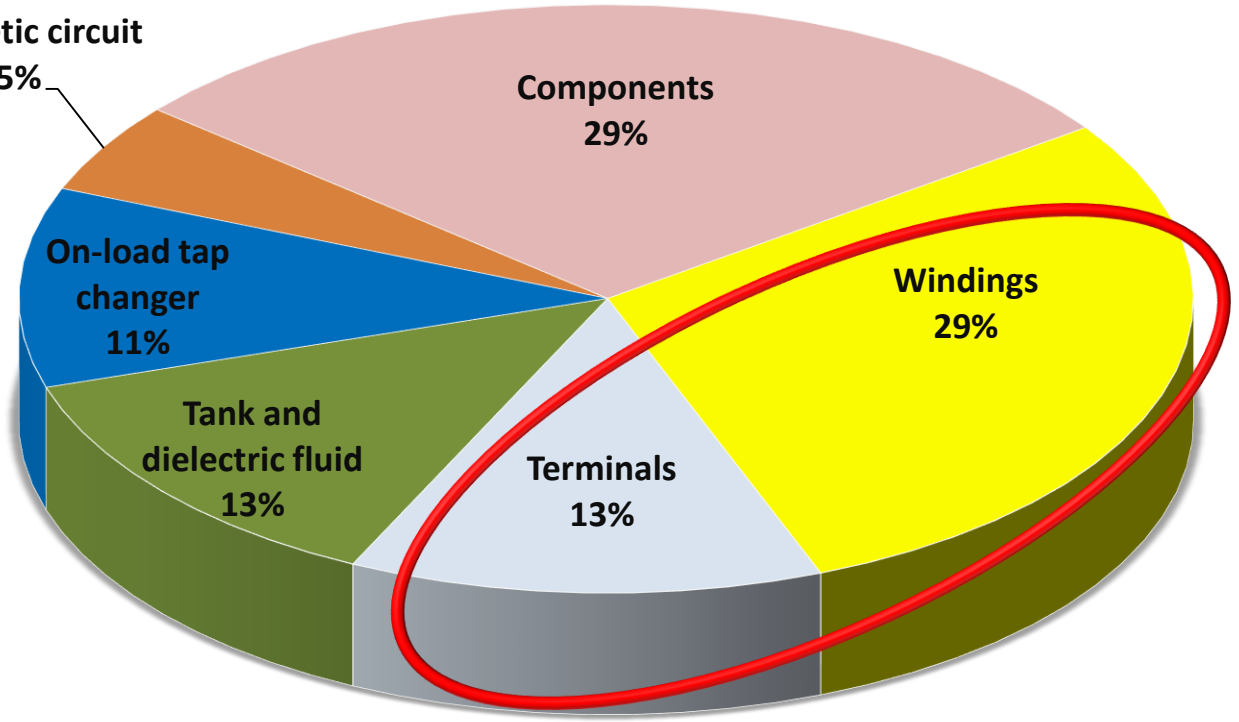


Surface

- **Loose windings**
- **Slot discharge**
- **Contamination**
- **Inadequate spacing**

Causes of partial discharge in Transformers

Percentage of Failures in Power Transformers



Source: Cigré WG 12.05 reliability study circa 1983

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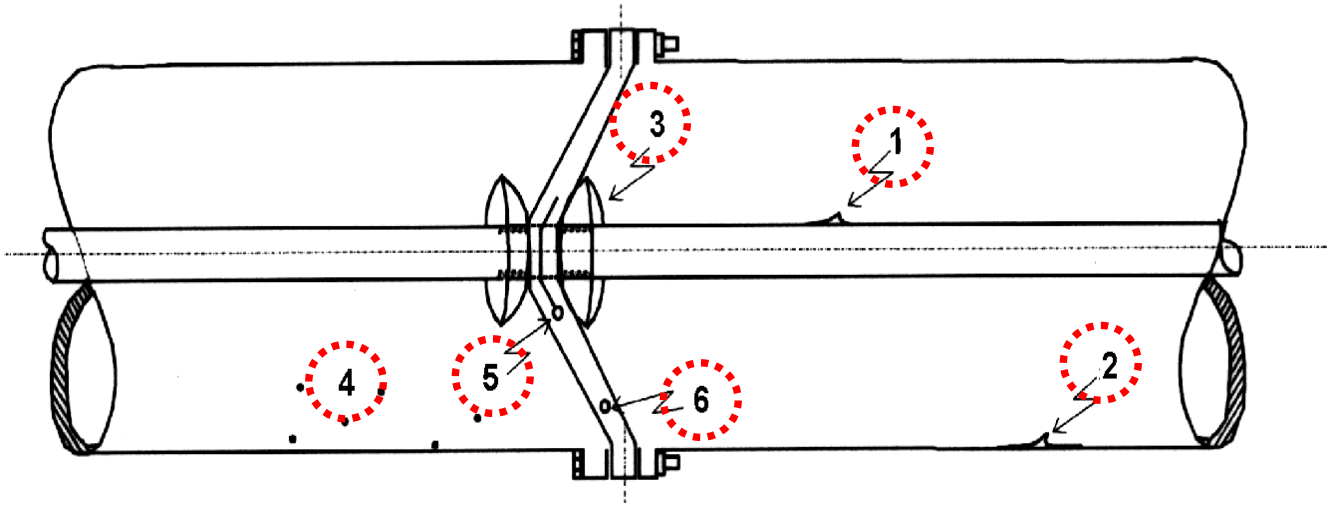
Causes of partial discharge in GIS



1- protrusions on conductor (fixed particle)

2- protrusions on enclosure (fixed particle)

3- floating parts (bad galvanic contact)

4- free particles on live parts and insulators

5- voids (delamination) between screens and insulation

6- voids and treeing in insulation

Partial discharge in Switchgears

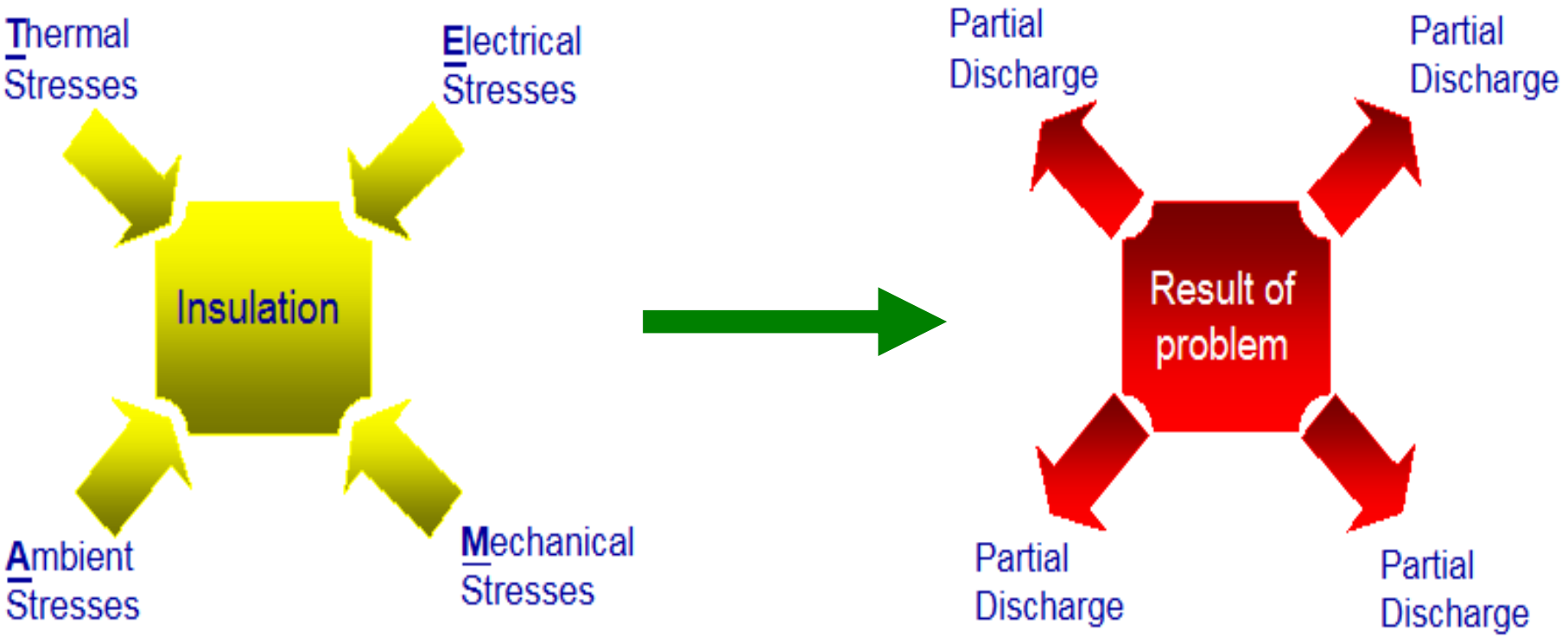
Surface Tracking occurs during normal load voltages

Evidence of Surface Tracking

Partial discharge in Cables

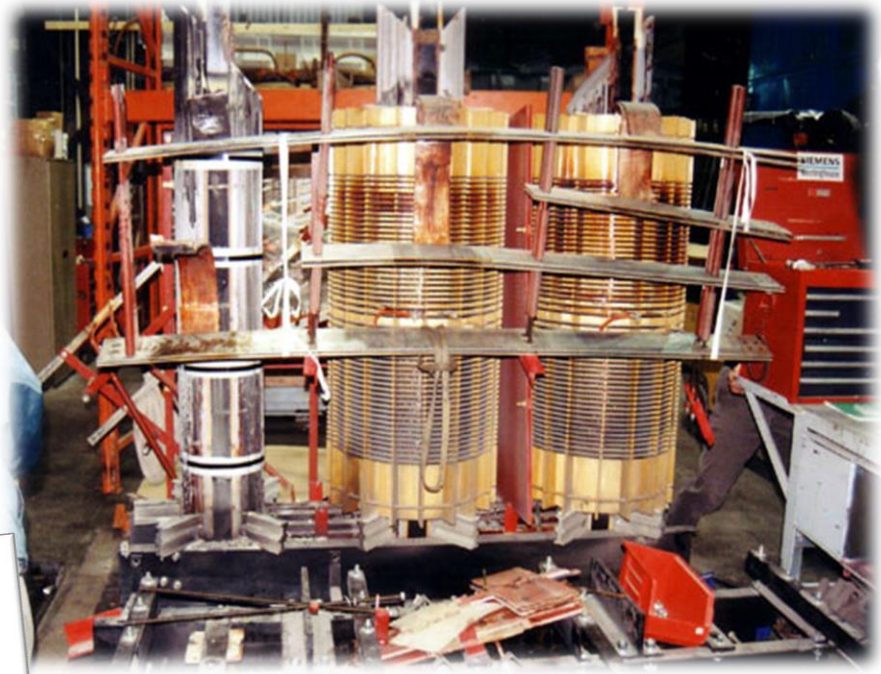
It is very important to detect partial discharge on **cable joints (XLPE/EPR type), switchgear, elbows, Cable Terminations,**

General sources of Partial Discharge?



Motor Stator Winding Failure


Yale


SIEMENS

The following movie will show us real PD pulses occurs within the insulator

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Why Monitor PD?

PD monitoring enables you to do the 3 "**Rights**" of maintenance:

the **Right** maintenance on
the **Right** machines at
the **Right** time

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5 Advantages to monitor PD :

1. ***Avoid unnecessary rewinds on older machines by maximizing the operating hours***

Why rewind if the winding is still in good shape?

2. ***Extend the Lifetime of Your Winding Insulation***
3. **Extend up-time between outages**
4. ***Reduce Capital Costs***
5. ***Maximize Production Revenue***

More 5 Advantages to monitor PD :

6. *Simple, Safe, and Inexpensive to Test*
7. *Find problems on new machines which may still be under warranty*
8. *Confirm Effectiveness of Repairs*
9. *Non-Destructive Test*
10. *Accomplish all this while the machine remains in operation (On-Line)*

PHYSICS OF PD DETECTION

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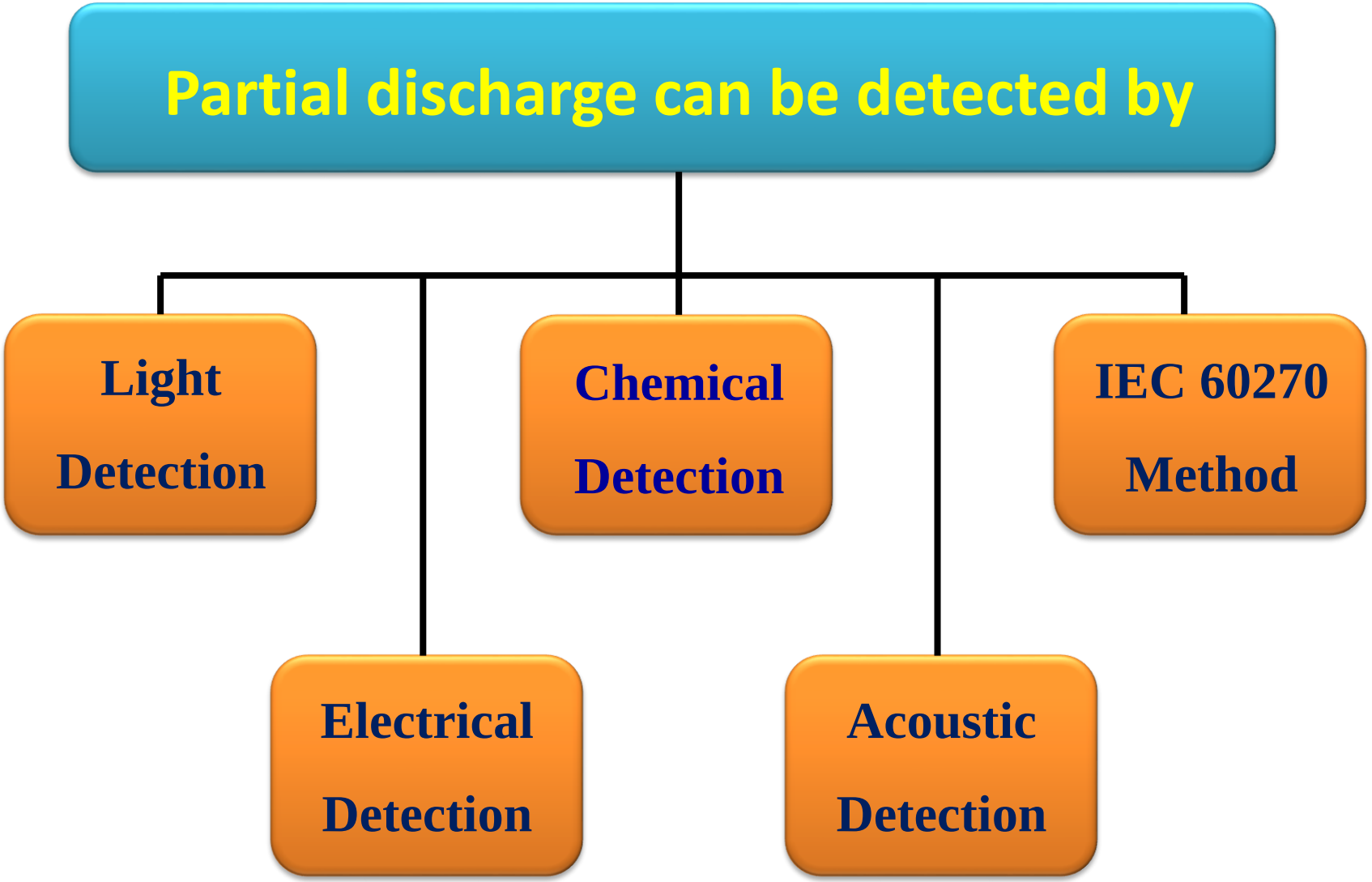

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Light Detection

Method: high sensitivity photomultiplier near HV parts.

- **most sensitive**
- **radiation in the UV band**
- **strongly absorbed by glass and SF6 - powerful laboratory technique for basic research**
- **not practical for online monitoring of GIS**

Chemical By-products

Method: Chemical reagent tubes or gas analyser.

- **immune to electrical interference**
- **for a steady discharge, diagnostic gas should rise to a level where it can be detected**
- **small volume lab tests, a 10-15pC discharge can be detected after some tens of hours**
- **insensitive due to large volumes of gas in GIS**
- **Shows total integrated equivalent PD over time (similar to DGA)**
- **although still being studied - some success in smaller GIS gas compartments**

Acoustic Emission

Method: Accelerometers or Ultrasonic microphones

- **sensitive, particularly for particles on chamber floor**
- **features of the acoustic signal can infer the shape and movement of a particle**
- **the measurements can be made external to the GIS**
- **commonly used during site acceptance testing, easy to use**
- **accurate location by finger printing along GIS or by time of flight using two sensors**
- **attenuation of signal is high, particularly on barriers so unsuited for detection of void type defects**
- **often used to backup UHF technique or where UHF cannot be applied**
- **not suited to permanent monitoring as too many sensors would be required**

Acoustic Emission - Detection

Pistol for simple location

More sophisticated analyser

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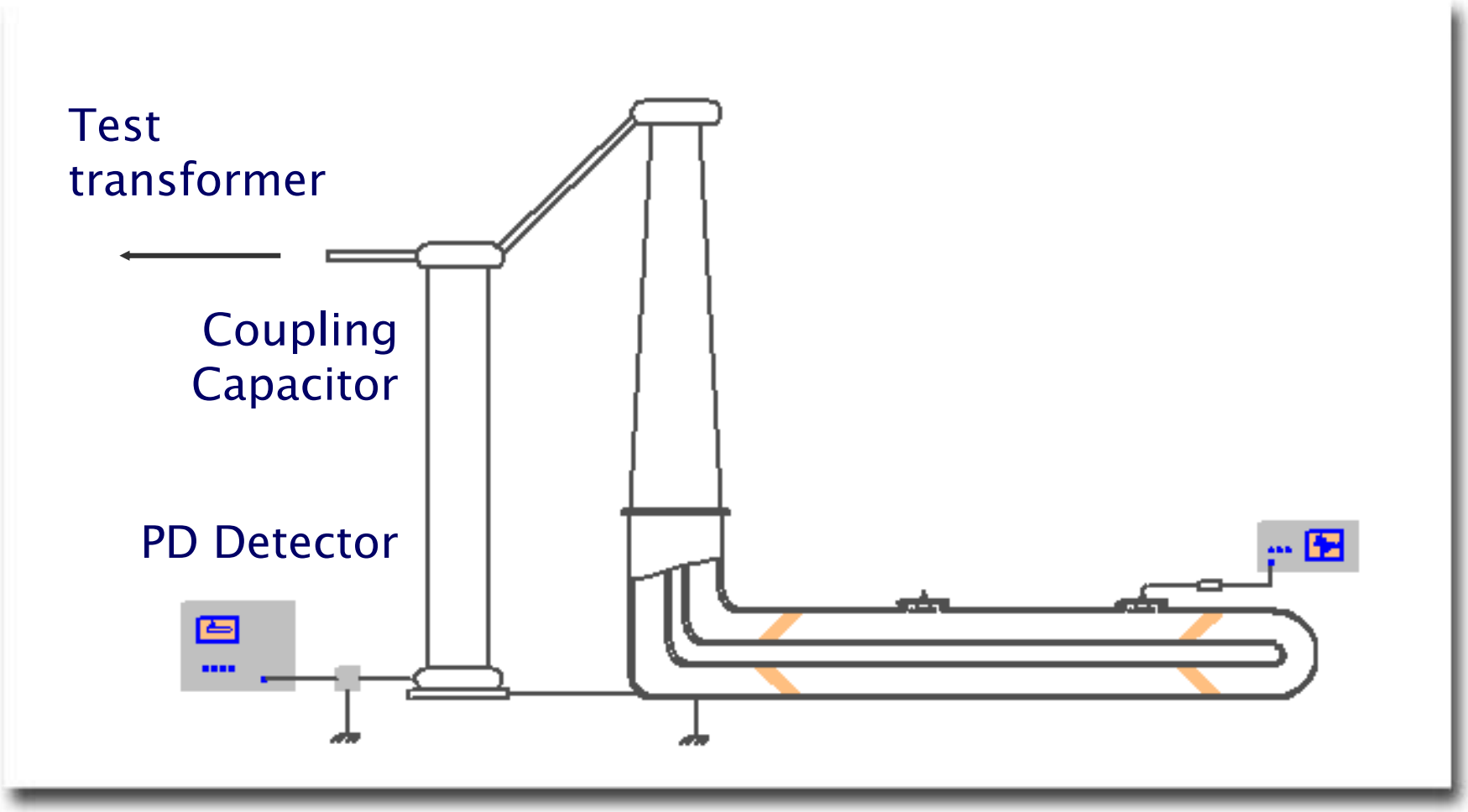
Conventional IEC270 Method

Method: Coupling capacitor connected to HV part

- **industrial standard**
- **calibrated in PC**
- **for maximum sensitivity, requires completely shielded test arrangement**
- **total capacitance of GIS is high and must be divided into sections for tests**
- **no means to locate discharge**
- **no coupling capacitor on GIS, hence method cannot be used for in-service measurements**

Conventional IEC270 Method



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Electromagnetic Detection

Method: Electric field sensor near HV parts

- **signal is easily detected if noise can be eliminated**
- **for GIS the UHF band offers very high sensitivity to all defect types and good noise rejection**
- **allows relative PD amplitude and pulse activity to be measured**
- **signal contains information on the type of defect producing the PD so defect classification is possible**
- **time of flight measurement using two sensors allows accurate location of discharge**
- **high sensitivity of field sensors means that large sections of GIS can be monitored effectively**
- **preferred method for site testing of EHV GIS**

CIGRE Investigation (1992)

Cigre conducted an evaluation of the various available PD detection methods in 1992:

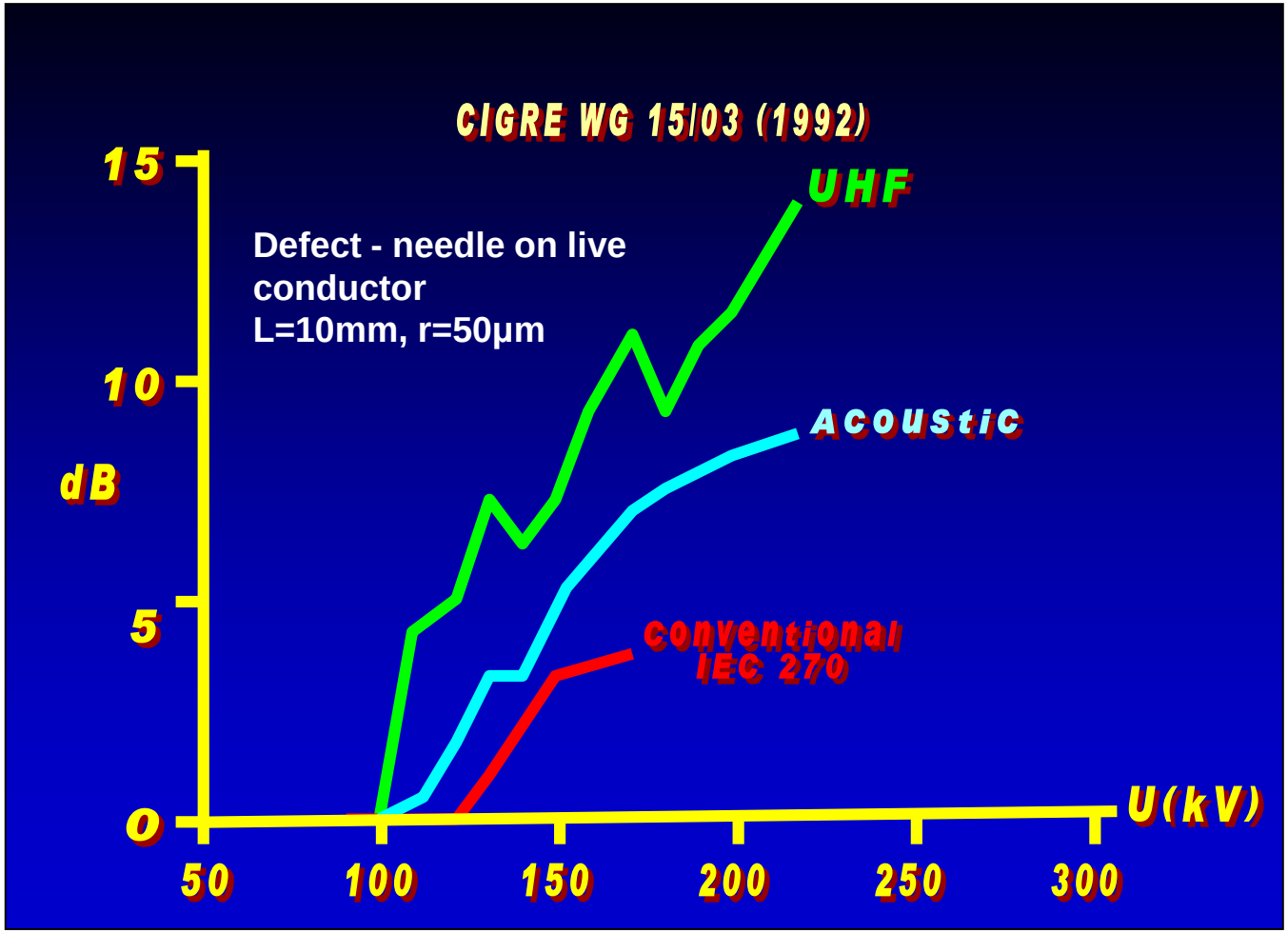
- **conventional PD to IEC270**, with either a standard detector at 1MHz or the PRPD evaluation system at 200MHz
- **UHF** using an internal coupler up to 1500MHz
- external **acoustic** emission sensor at 34kHz
- **chemical** using detector tubes

CIGRE Investigation (1992)

The study concluded:

- acoustic, conventional and UHF techniques show good sensitivity
- acoustic methods are non-intrusive but attenuation of signal across barriers and along chambers is high
- conventional measurements need external coupling capacitor and cannot be used on GIS in-service
- **UHF technique suitable for in-service monitoring**

CIGRE Investigation (1992)



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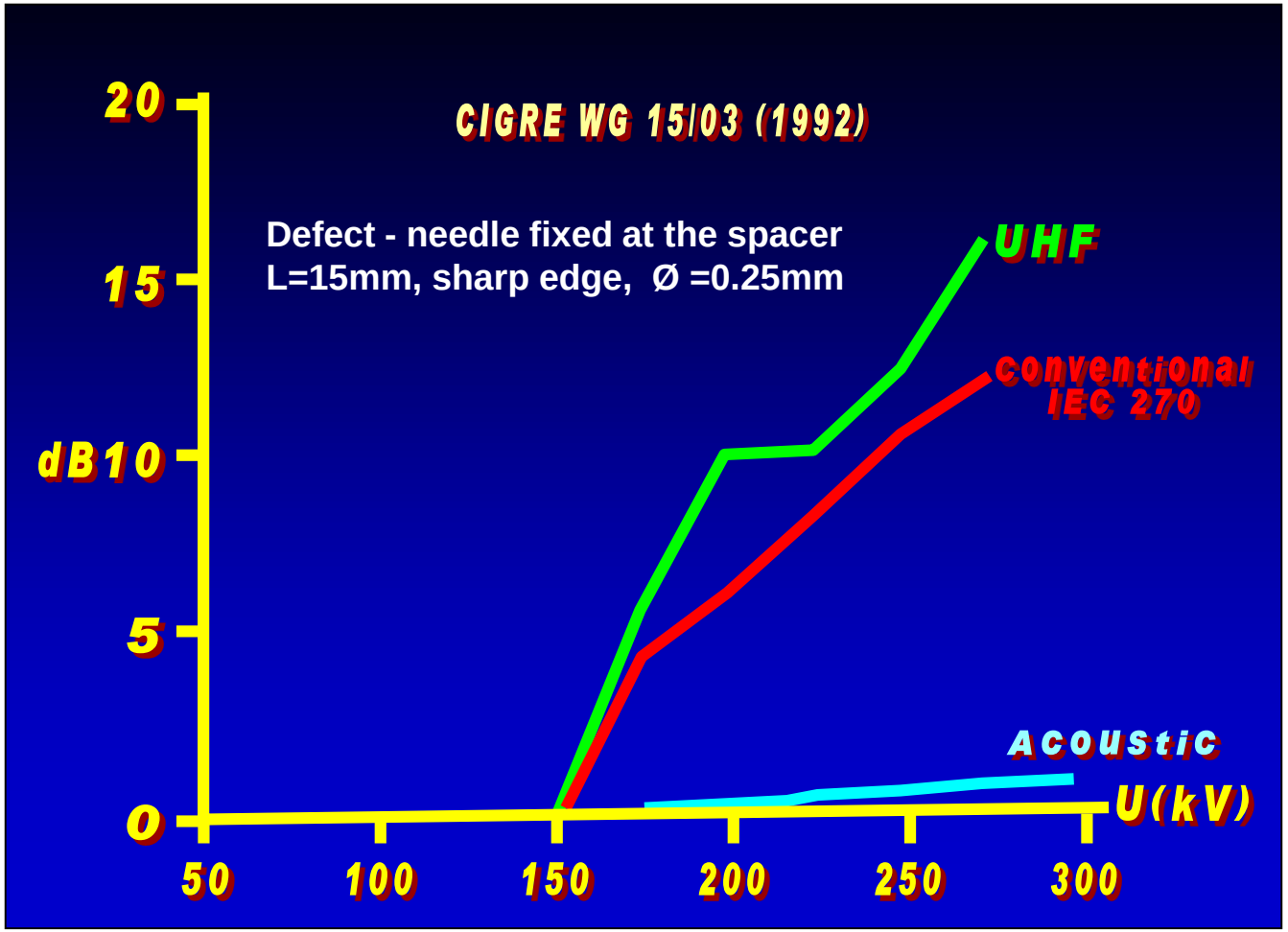
CIGRE Investigation (1992)



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Relative Merits:- UHF and Acoustic PD Systems

	UHF-System	Acoustic-System
Main purpose	☺ detection & 😐 localisation of PD sources	☹ detection & ☺ localisation of PD sources
Sensitivity	mobile particles (1-2mm), ☺☺ fixed particles (2-5mm) floating components voids in spacers	mobile particles, 😐 fixed particles, floating components ☹ voids in spacers
Measurement time / bay for spot checks	☺ 5-10 minutes, easy and fast	☹☹ min. 30 - 90minutes "one has to crawl on GIS"
Suitability for on-line continuous monitoring	☺☺ Reliable sensors, noise immune and large sensor spacing	☹☹ Unreliable sensors, noise issues and needs many sensors

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Relative Merits:- UHF and Acoustic PD Systems

	UHF-System	Acoustic-System
Typical system requirements	😐 built-in sensors, ☺ (or in some cases external spacer sensors)	☺ no built-in sensors required !
Noise reduction	☺☺ very effective,	☹ not possible, **additional** noise sources: wind, rain droplets, vibrations, air corona
Data storage	☺ easy and fast on PC	😐 only possible with AIA type instrument
Data analysis during and after measurement	☺ easy and fast, use of PD database for analysing and classifying data	😐 AIA system: possible to some extent

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What Makes a UHF PDM System so Effective:

- can detect all known types of PD in GIS, Transformers or rotating machines
- can record data in a way which allows the analysis of PD using expert system PD pattern interpretation by ANN and feature extraction
- can instantly warn of active PD (no time delay)
- gives indication of the type of PD and therefore helps in determining the risk of failure

What Makes a UHF PDM System so Effective:

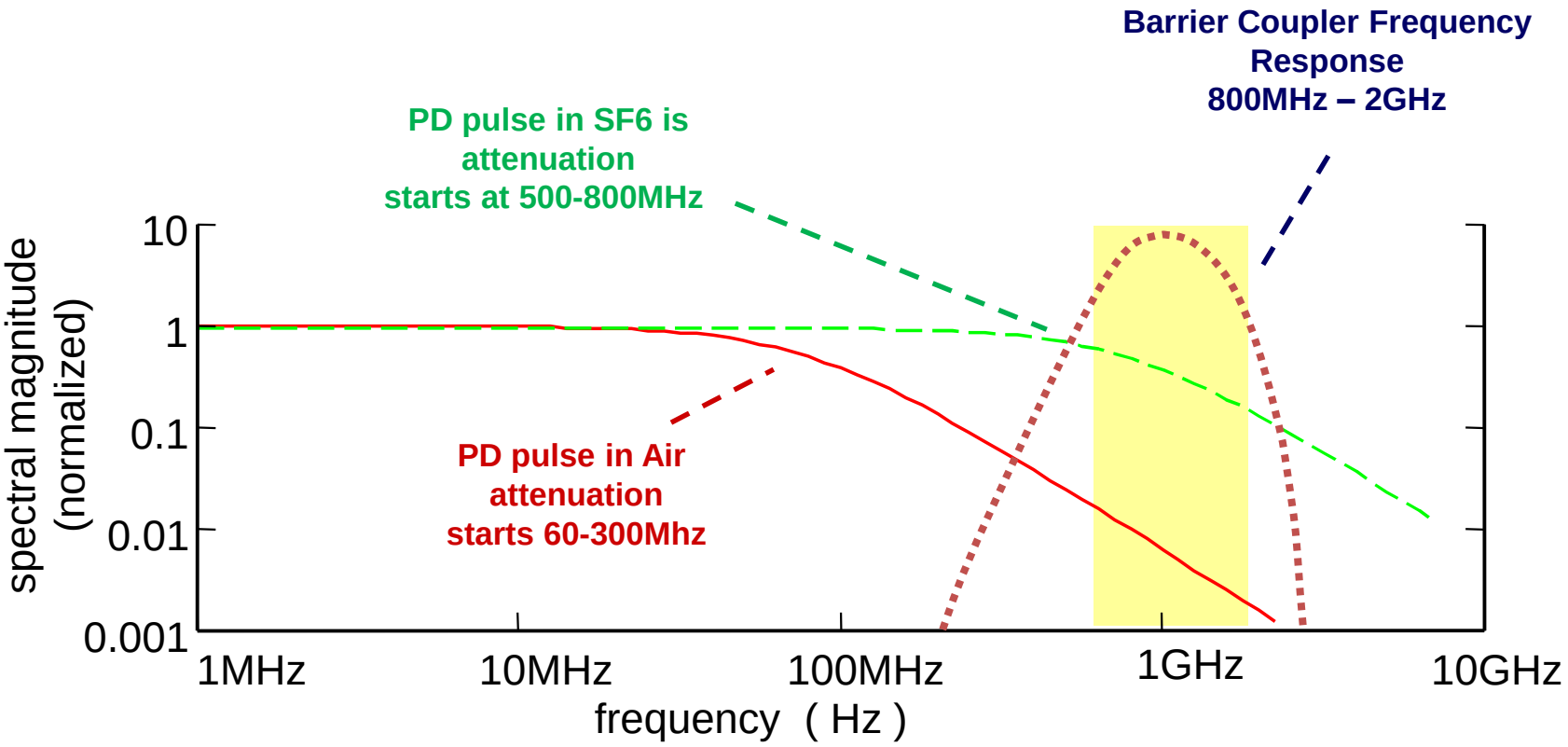
- suitable for periodic and continuous, on-line monitoring in-service
- applicable to all system voltages
- only IEC approved technique for use during HV commissioning tests (of GIS)
- Also suitable for other metal enclosed electrical plant such as, dead tank CBs, cable end boxes and switch-panels

What Makes a UHF PDM System so Effective:

- The UHF method can reject external “air corona” produced noise, as this occurs at lower frequencies (HF and VHF)

- This is because the “fast” PD pulses in SF_6 or Oil produce strong signals at frequencies much higher than normal “air corona”

Physics of PD Attenuation



Best SNR with still sufficient sensitivity 1GHz±300MHz

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Questions ?